THE BOOK WAS DRENCHED

INTRODUCTION

Our era has often been called "The Century of Science". As we look back from our vantage point at the middle of this century, we can see that few or none of the important questions of science have remained in the condition in which they were in 1900. In every field or science there have been fundamental changes in point of view, and this is a mark of progress, since science is in a sense a continuous adaptation to new knowledge.

In some cases the change in point of view is so great as to be "revolutionary". Future generations will probably so regard the changes in biology and its applications brought about by the establishment of the laws of heredity. It was this first half of the twentieth century that witnessed the rise of the science of genetics, responsible for a radical change in the way in which race and race differences in man are to be regarded.

The judgment of biology in this case is clear and unequivocal. The modern view of race, founded upon the known facts and theories of heredity, leaves the old views of fixed and absolute biological differences among the races of man, and the hierarchy of superior and inferior races founded upon this old view, without scientific justification. Races appear in the new view to be biological sub-groups within the single species, *Homo sapiens*, in which the similar heredity which the whole species has in common far outweighs the relative and minor ways in which the sub-groups differ. This change in biological outlook has tended to restore that view of the unity of man which we find in ancient religions and mythologies, and which was lost in the period of geographical, cultural and political isolation from which we are now emerging.

The way in which this radical change in view about race came about is intimately connected with the discovery of the mechanism of biological heredity. Biological heredity is what is transmitted over the living bridge of egg and sperm, which is the sole biological connexion between the generations. It is necessary to specify it as *biological*, since all

humans are strongly influenced by *cultural* inheritance as well, which is transmitted outside the body, such as language, custom, education and so on.

Although the internal hidden stream of biological heredity passes continuously from parent to offspring only by means of the single reproductive cell, its effects or manifestations in the individual depend upon the conditions under which he lives. It is obvious that we cannot inherit characters as such, for physical traits such as height or skin colour and mental ones such as mathematical ability cannot be present as such in the minute single cell from which each human being takes his origin. What is transmitted by biological heredity is a set of specific potentialities to respond in particular ways to the environment. A person who has "inherited" musical talent only exhibits this under certain conditions. The same is true for physical characters, but in less obvious ways, since the response may occur very early in development, as in the case of eye colour, hair form, and similar traits. Biological heredity thus consists in the passage from parents to child of a set of abilities to respond to a range of possible environments by developing a particular set of characters. A human being, like any other living thing, is always a product of both his heredity and his environment.

What is the physical means by which this transmission of heredity occurs? Before 1900 it was thought of as the passage of something from the parents which, like a fluid substance, could mingle and blend in the offspring. The contribution of each parent, popularly referred to as "blood", was assumed to lose its own individuality in the blend which occurred in the child, and this blending process repeated itself in the children's children and in later descendants. Each person was supposed to have inherited half of his nature from each parent, hence one quarter from each grandparent and so on in decreasing fractions from remoter ancestors. If the parents differed in race or type the children were "half-bloods", the grandchildren "quarter-bloods", etc.

Although this blending or blood theory had some support from observation (for example, the descendants of parents differing in skin colour or in height are often of intermediate colour or size), it was based on an assumption which has been shown to be erroneous. This assumption was that the hereditary material was infinitely divisible and miscible like a solution. As early as 1865, Mendel, the founder of genetics, had shown that heredity consists in the transmission of dis-

crete elementary particles, now known as genes. Genes are stable living units, perhaps the smallest units in which living matter can perpetuate itself; their peculiarity is precisely that they do not blend or lose their individuality in whatever combinations they take part.

Mendel's theory, now known as the gene theory, was extended to all animals, plants and man in the period after 1900, in which year it was independently arrived at or "rediscovered" by three other scientists. It is generally recognized by biologists as providing the most reasonable basis for explaining the facts of hereditary resemblances and differences. Although only a beginning has been made in working out its implications for other scientific questions such as evolution, and its practical uses in agriculture and medicine, it is already apparent that the theory of the gene is one of those basic ideas, like the atomic theory, which lie at the bottom of our understanding of many material phenomena.

It is not strange, therefore, that views about race differences in man should have been so much affected by the gene theory. Under the old blending or blood theory we should expect the descendants of parents showing hereditary differences to become more and more alike. We should thus expect pure races to arise and to become uniform, even though they had originated from a cross of two unlike races. Blending should obviously lead to the disappearance of variability, of differences between related individuals.

If on the other hand, the biological characters are perpetuated through the transmission of genes which do not blend, then we should expect hereditary variability, once it has arisen, to persist indefinitely. In a species like man, in which the normal pattern of reproduction is by marriage of unrelated or distantly related individuals, differences due to genes, if they do not blend and are not altered by the combinations in which they occur, should be preserved. Each population, whether family, tribe, or racial group, should thus consist of individuals differing from each other, to a greater or lesser degree, in hereditary characters. Consequently "pure races" should not exist, in the sense of groups of identical individuals or even of individuals corresponding to some ideal racial type; and races might be expected to differ from each other in relative rather than in absolute ways, since the same elements (genes) might circulate through them because of occasional intermarriage either in the present or the past.

As we look upon the present human inhabitants of the earth, there is little doubt that what we see resembles closely what we should expect if the gene theory is true. All men clearly belong to one species, being alike in all the fundamental physical characters. Members of all groups may intermarry and actually do; this condition has apparently obtained for a long time, since different groups of primitive man were also races of one species. This is probably because all got most of their genes from a common source, by descent from common ancestors. Yet every man is unique and differs in minor ways from every other man. This is in part due to the different environments in which people live and in part to differences in the genes which they have inherited.

For although genes are not changed by the company they keep and have been proved not to undergo blending or contamination, they do sometimes change spontaneously by a process known as *mutation*. An old gene which has been passed from parent to offspring for many generations may suddenly reproduce in a new form. An old gene which led to development of dark skin colour may give rise to a new gene which is unable to produce pigment, and colourless skin or albinism results. Instances of this have been known among the white, black and yellow kinds of men, so it seems to occur independently of race, skin-colour, or environment. It is certainly not an adaptive change, that is, one that makes the person better fitted to his environment, since albinos, for example, are at a great disadvantage, particularly in the tropics. The fact that mutations do not appear as adaptive responses to the environment indicates that the origin of new characters is not to be sought, as it was in the days before the rise of genetics, in the inheritance of acquired characters.

The origin of new genes by mutation is apparently the source of the hereditary variability by which individuals and groups of men are distinguished. How the common store of genes with which our species began was changed and distributed among the different groups of mankind will have to be examined in later chapters. Here it should be emphasized that the revolution in thinking about race which has resulted from twentieth century studies in biology sprang from two main sources: (a) the proof of the gene theory of heredity and the disproof of the blending or blood theory; (b) the discovery that new genes arise by a random process of mutation, and not from the direct effect of the environment.

I. WHAT IS RACE?

The chief purpose of this pamphlet is to make clear a modern biological view of race, which will necessarily be based on the evidence now available. This is certainly not complete and is sure to increase through the efforts of anthropologists, geneticists, and others who are actively studying the complex problems of human biology.

But although we do not know all about race, we are in the position in which scientific study often finds itself, of having good evidence that certain views once generally held are definitely wrong. In the zig-zag process of learning, advance is often measured by the retreat from error. We know now why certain views about race uniformity and purity and the fixity of racial differences were wrong; and why social and political views of race inequality were wrong. Since the former were often used as a justification for the latter, we should as reasonable beings like to believe that, if we get rid of our biological misconceptions, we should thereby cure the social and political ills of injustice and exploitation which appeared to be based upon wrong biology. Eventually we may expect this to happen, but we should not forget that the way in which human beings as individuals and as groups have acted with regard to race differences has more often stemmed from feelings and from prejudice than from knowledge. Knowledge eventually overcomes prejudice, but the delay may be long unless active steps are taken to implement the improvements in knowledge.

This is clearly illustrated by the fact that although there has been for some time a considerable measure of agreement amongst biologists about the concept of race in plants, animals and man, the word *race* as generally used has no clear or exact meaning at all, and through frequent misuse has acquired unpleasant and distressing connotations. Many people become confused when the direct question is put to them as it is in some official documents: "To what race do you belong?" One has to stop and ask oneself: "Now why do they want to know that?" The existence of that question

is evidence of past misuse. Sometimes a question about race is intended to reveal one's national origin, and the answer to that question might be French or Lebanese or Brazilian or American. But everyone knows that political entities are made up of people of many different origins. One has only to think of the U.S.A., in which persons from every part of the world are "Americans", to see that race and national origin are quite different ideas.

Everyone in Germany in the Nazi period knew what a question about race was intended to reveal, for the nation was divided into two categories, Aryan and non-Aryan. Non-Aryans were persons with one or more grandparents who had been listed as Jewish. Aryans were the others, some of whose ancestors might have come from northern or eastern Asia or other non-Aryan regions. The intention of such a question was to facilitate a political classification and disfranchisement. What it actually did was to set up two "races" and to define one by an ancient and outmoded linguistic term ("Aryan") and the other by the religion of some of one's forbears.

In some countries the immigration laws and the forms for sorting out applicants for schools or the professions still retain such questions.

Answers to them usually serve the purposes of racial discrimination rather than of providing reliable information, since it has proved extremely difficult to frame questions about individuals in such a way as to reveal their "race". Before such questions could have scientific value we should have to have a list of all of the "races" of the world about which general agreement had been reached. Such a list does not exist, because anthropologists have not reached a general agreement on the exact racial classification of mankind.

Owing to its bad connotations and the absence of such an objective list, doubts have been expressed whether there is any valid and useful meaning of the word at all which would justify its retention in our vocabulary. I believe a word like this is needed to denote a biological category, which although difficult to delimit, is a real factor in the structure of the human population of the earth. It seems better to define and explain its use, and to free it from its bad and false meaning, than to give up the problem by excluding the word.

Nearly all peoples have the idea of blood-relationship and

knowledge of biological kinship, and consequently nearly all languages require a word to express it. "Race" is one of these words. We know that all men living today are descended from common ancestors and are thus blood relatives. The expression "the human race" embodies this established fact. Sometimes we call ourselves "the human family", and this is also sound usage. In many languages "race" and "family" are used more or less interchangeably.

What makes biological relationship is of course sharing a common biological inheritance. Blood relatives have access to the same store of genes which pass over the biological bridges connecting the generations. A kinship, therefore, must be, biologically, a community of genes. In the sense that all men are related, however distantly, through intermarriage among their ancestors, the whole human race is one community of genes. It is biologically true that of the many thousands of hereditary units, genes, which any person inherits, the vast majority are the same as those in any other human being. These are the genes to which we owe our humanness. Many of them were derived from our animal ancestors; some of them, and particularly the combination in which they appear, are unique among animals and set us off as a species from all others; the species *Homo sapiens* keeps its peculiar inheritance because it does not exchange genes through crossing with any other species.

But within this great community of man there are smaller communities between which there is little or no intermarriage and this partial biological separation or isolation is accompanied by differences between the groups as regards the frequency with which certain biological characters appear in them. Thus, most of the inhabitants of Africa have dark skins, and since this persists in persons of African descent when they live elsewhere for many generations, as in America, it is biologically inherited. Negroes resemble each other in this trait and differ in it from persons of most other geographical areas. The Europeans, the mongoloid peoples of Asia, the aboriginal inhabitants of Australia are, as groups, recognizably different from each other. The characters by which they differ, as groups, are of the same sort as those by which individuals differ from each other.

Look for example at the kind of eyelid which we think of as Mongolian. It has a fold of fat which obscures the outer portion of each eye and makes the eye appear narrower and more slanted than the eyes of Europeans or Negroes. Mon-

golians have no monopoly of this kind of eyelid. It appears in other peoples as well and is occasionally found as an individual variation in Europeans, especially in children. Or take the tightly curled hair which we think of as negroid. Hair almost exactly like this has been found in families in Norway and in Holland which are unrelated to each other and to Negroes, at least in historic times. We know that both the eye-fold and the woolly hair form depend upon a particular inheritance in which brothers and sisters of the same family may differ.

This illustrates an important fact. Racial differences, even those of the major "races" above mentioned, are compounded of many individual inherited differences. This means that races are distinguished from each other, as *groups*, by the relative commonness within them of certain inherited characters. Thus the Mongoloid eye-fold is very common in mongoloid peoples, but uncommon in Europeans. Woolly hair is very common in negroid peoples but uncommon in Europeans or Mongolians. It is more accurate to describe the difference in this way than to say of any one trait that it is present in all of one group and completely absent in the other. Most people would have said this of woolly hair--present in all Negroes, absent in all Europeans. But when the first woolly haired Norwegian child was born, the statement became untrue, and this could happen for any one of the "racial" traits. We are going to find out later how these *new* traits arise. In respect to any one "racial" character, such as hair form, the relative commonness could change quite quickly. If it were of any advantage to Norwegians to have woolly hair, either biologically or esthetically, the trait could spread from the small family which shows it now.

This illustrates another point about racial differences. Sepa rate racial traits may change their frequency, that is to say, the "race" is changeable, even in respect of heredity characters. Of course this is a slow process when many characters are involved, and races are usually distinguished from each other by many differences. But it is evident that if racial differences are particular collections or aggregates of the traits by which individuals may differ, and if these traits are subject to change by mutation, then "race" is not a fixed or static category but a *dynamic* one. Biologically, a race is a result of the process by which a population becomes adapted to its environment. The particular array of traits which come to be the most frequent, and hence to charac-

terize the group, are probably those which now or at some past time proved to be successful in a particular environment.

This then is the sense in which the word race may have a valid biological meaning. A race, in short, is a group of related intermarrying individuals, a population, that is, which differs from other populations in the relative commonness of certain hereditary traits.

It is true that a definition like this leaves a good deal of latitude in deciding how big or how small a race may be, that is, how many people shall be included in it, and also in deciding how many races we shall recognize. These last are matters of convenience rather than of primary importance. What is important is to recognize that races, biologically, differ in relative rather than in absolute ways. The race gets its character from the commonness within it of hereditary characters which are not uniformly present in every member. Its stability depends on the durability of the genes responsible for the hereditary characters, and upon the habit of marrying within the race rather than outside it. When either of these changes, then the race changes. From this it must also be evident that there is in the human species no such thing as a pure race in the sense of one in which all members are alike; it is improbable that there ever has been or ever will be such a race of men.

II. HEREDITY AND ENVIRONMENT

The character of every human individual and of every human group is the joint product of its heredity and its environment. These influences have also been referred to as *nature*, that which is inherent, inborn, and *nurture*, the sum total of the external factors upon which the maintenance of life depends. There has been a strong tendency among most peoples to attribute the differences amongst themselves, and between their group and others, either to one or the other of these two influences. The influence of soil, climate, nearness to the sea and similar geographic variables are clearly apparent. But it is also evident that all people living under the same conditions are not alike, and that these differences are connected with the particular parents, family, tribe, or race from which they spring. Different people attribute different degrees of importance to environment and to heredity in shaping human individuals and groups such as races. They ask: "Is heredity or environment the determining factor" tending to divide into two groups, environmentalists and hereditarians.

To the biologist this is a false and meaningless dichotomy. None of the reactions which a human being displays could occur without a particular environment, which can vary only within certain restricted limits; and no one is born except from particular parents. Heredity is what the new life starts with, environment is what makes its continuance possible. Both are essential. What we need to know is how they act together in shaping the traits of individuals or races.

Let us take a careful look at heredity. We called it the living link or bridge between the generations. Actually what goes over that bridge are thousands of tiny particles, packed away in the single cell which each of us received from each of our parents. These particles are called *genes;* they are the physical *beginnings* with which our parents endow each of us at conception. What we inherit are *genes.*

From these beginnings the new individual develops by taking in food, first from the mother's body, later directly

from the outside world. The most remarkable part of this process by which a new individual develops is that, whatever he takes in, he converts into his own peculiar kind of substance. Lifeless food is not only made into a human being, it is made into a particular kind of person. The same food that is converted into a blond, blue-eyed, tall man who cannot distinguish between red and green colours of the rainbow and gets hay fever every August, is in his sister converted into a dark, brown-eyed, short person with good colour vision and no hay fever. This latter kind of difference seems to depend upon certain inside directors which determine how the body shall utilize its food and energy. In the brother and sister some of these directors are different. We have referred before to these internal directors as *genes* and later we shall see how they come to be different in brothers and sisters.

In spite of the fact that under certain conditions the brother and sister differ in complexion, one being light and one dark, under other conditions this may not be so. Let the sister spend a long illness in hospital, away from the sunlight, and let the brother work every day in the bright sun. The skin colour of one will get pale and the other will darken. Apparently the difference we saw first depends both upon genes and upon the sun; in fact we could say that the blond differs from the brunette in requiring more sunlight to reach a similar stage of darkness. They differ in responsiveness, and the internal directors or genes therefore do not settle the differences in an absolute way, but chiefly by deciding how the body will react to something in the environment. In the case of eye-colour the difference between brown and blue is settled chiefly by the genes before birth, and we know of no environmental difference that will change the eye colour, although we might find one by searching for it. On the other hand, the response which the brother expresses by sneezing and having a "running nose", the symptoms of hay-fever, can be avoided by keeping away from particular plants or kinds of food or by medication. Under these conditions we should not know he was different from his sister, who does not show this sensitiveness to the same plant or food. His heredity decides his reaction to a particular part of his environment, and in many cases this reaction can be changed by changing the environment. Many of us are susceptible to certain infectious diseases while others are not. Yet we all become alike when a drug is found which will kill the infection or the parasite.

Examples like this, with the great body of biological research since 1900, show what heredity is. It is the pattern of genes, derived from the ancestry, which determines the possible kinds of response to the environment. Hereditary similarity is the rule throughout mankind, because that particular pattern of genes has been handed down to us which was found by the harsh test of natural selection to give the most successful response to the environments to which our ancestors were exposed. Hereditary differences, except those newly arisen by mutation and hence not tested by natural selection, are usually concerned with less crucial or critical responses. In every race there are not only some people who are colour-blind, like the brother in the example above, but others who are unable to taste certain substances, that is, are taste-blind; others who are smell-blind, and still others sound-blind, or as we say, tone deaf. These differences between people have been shown to be due to differences in single genes, which decide how much light or taste or sound it will take to register a certain sensation in the brain. The study of such relationships, which is still in its infancy, has led to the following analogy. Heredity determines the nature of the internal trigger which the stimulus from the environment may release to produce a given effect. Some triggers are so constituted as to resist most of the range of pressures which are possible in an ordinary environment; for example, they fail to respond to the stimulus of red or green light and hence result in colour-blindness.

In elucidating the ways in which heredity and environment interact and estimating their relative roles in determining particular traits, nothing is more instructive than comparing a character in the two kinds of human twins. Whenever two babies are born at once, one of two things has happened. Either two eggs which happened to be present, instead of the usual one, were fertilized by two sperms and two different individuals thus got born at once; or else one egg, after fertilization by one sperm, separated into two parts and each part became one of the pair of twins. The first case is like the birth of ordinary brothers and sisters except for their being born at the same time. The second is like the duplication of a single individual. The difference is important, because ordinary brothers and sisters, coming from different eggs and sperm, may get different genes; while two individuals arising from a single egg and a single sperm, must perforce have the same genes. Any differences in the latter

therefore cannot be due to heredity, and we have a measure of the degree to which heredity can control a particular trait; and conversely of the degree to which environment can modify an hereditary trait.

We have all been struck by the extreme similarity between this kind of twins; they are always of the same sex, have the same kind of blood and the same bodily and facial and even mental features, and they react similarly to diseases and to education. These are the "one-egg" or identical twins; and since they have the same heredity, any differences we see in them must be due to environment. They do show some differences in spiritual and emotional responses, and some physical traits such as weight may differ a little, but otherwise they remain extremely similar even when separated at birth and reared in different homes.

Members of the other kind of twin pairs, those arising from two eggs (often known as fraternal twins), are no more alike than ordinary brothers and sisters. They exhibit the usual gene differences to be found in any family, and as often as not are of opposite sex.

The greatest biological interest attaches to comparisons of the conditions of single traits in the members of the two kinds of twin-pairs. In the classical blood groups (A, B, AB, and O, see p. 28 for details) and in all other blood factors so far studied, the members of all one-egg twin pairs are exactly the same, that is, they show 100 per cent concordance, whereas two-egg twin pairs may show discordance in the blood group. In the case of the AB groups only about 25 per cent of the two-egg twin pairs are concordant. This alone would indicate that the blood group of a person is probably determined entirely by the genes which he has inherited, and that differences in environment encountered after birth are powerless to change it. The differences in this respect between two-egg twins and between brothers and sisters are known to be due to the transmission of different genes in different eggs and sperm of the same parents, whereas no such differences could occur within the single egg which gave rise to identical twins. Other traits can be arranged on a quantitative scale according to the relative degrees of concordance which they exhibit in one-egg as compared with two-egg twins, and this scale serves to arrange the traits in the order of their sensitiveness to environmental influence. Physical traits in general show high concordance in one-egg twins; in reaction to mental measurements one-egg twins

also show greater resemblance than two-egg twins, though the effects of education are clearly in evidence. In reactions to emotional tests there is less difference in the amount of concordance and apparently a greater effect of environmental influences.

One of the chief lessons learned from studying twins, as well as by other methods, is that each individual inherits many potentialities. Some of these, like our blood-types, are realized in all the environments which a human being encounters. These we call hereditary. Others, such as the resistance which we exhibit to certain diseases, and particular mental and emotional reactions, are realized only in certain environments. Variations in these we call environmental. But variation in all of these characters depends on the same biological principle: what human beings are is determined by the way in which the hereditary nature responds to its environment.

III. THE ORIGIN OF BIOLOGICAL DIFFERENCES

Since all men do not respond in like ways to a similar environment, there must be differences in heredity between persons and groups similar to those between two-egg twins and brothers and sisters. This indicates that there must be some biological mechanism which preserves the general resemblance between parents and offspring, while permitting at the same time particular differences between related persons. Heredity in common parlance is the name usually applied to the transmission of resemblances, but since a lack of resemblance, a variation, may be transmitted—once it has appeared—with equal fidelity, the mechanism of heredity must be viewed as the means by which both resemblances and differences are perpetuated.

As indicated in the first chapter, if the material particles, the genes, remained always the same, all human beings who are descended through hundreds of thousands of generations from the same ancestors would have remained alike in all hereditary characters. In general of course they have remained alike in all hereditary characters and this means that every one of the thousands of genes nearly always makes an exact duplicate of itself each time a new cell, a new egg or sperm, is formed. Thus in general the offspring get descendants of the same genes that the parents had, and hence resemble them.

But once in a while when a gene makes a replica of itself, the copy is not quite exact, and the new gene produces a different effect. That is what happened when the first person with woolly hair appeared in a Norwegian family. Suddenly woolly hair appeared in one child of two straight-haired parents, from families which had never contained a woolly-haired individual. This child transmitted woolly hair to some of his children, and now a number of Norwegians, all related by descent to the original woolly-haired individual, have this quite un-Norwegian type of hair. This kind of sudden change in a gene is called a *mutation.* Perhaps the first man from whom the Negroes inherited woolly hair got it in this way,

by mutation, although the story is probably more complex than that; or perhaps human hair was first woolly and a gene mutated from woolly to straight and thus Indians and Europeans got their straight hair. How it happened in history is not known; nor is it known exactly how mutations occur today, in spite of the extensive biological research on this question during the last 20 years. What is important for an understanding of race differences is the fact that *mutations do happen*. It has been shown that genes can change suddenly from one state to another, in somewhat the same way as a light can be switched from bright to dim and back again.

The effects of such changes may be observed as hereditary variations in the structure or functioning of the several systems of the human body—white spots on head or body, various diseases, skin colour, eye-defects, dwarfism and many other variations have arisen in this way. In fact this is probably the chief or only source of new hereditary variations in man, as it is in animals and plants generally. In general mutations arise suddenly, appear not to be adaptive responses to environmental agencies, and are generally less useful or desirable than the condition from which they arose. It is known from experiments with animals and plants how to make mutations happen more often. Treatment with X-rays, radium, and certain chemicals will make it more likely that an old gene may change into a new one, usually in a less useful form than the old. The effect seems to be directly on the gene rather than by way of a change in the body of the parent. In this way the origin of new genes by mutation, even when brought about artificially, is quite different from the method by which some of our grandparents thought that new characters arose. It used to be supposed that changes in the body or mind, such as greater muscular development, came about in response to the needs of the body, and could be passed on as such to the children. It is in one way unfortunate that this does not occur, for all of us have to begin to learn where our parents began and not where they left off. On the other hand, we are glad to escape the mutilations and deleterious changes caused by accident or disease in our ancestors. There is no evidence that new hereditary characters arise by direct effects of the environment or in response to need. Such acquired characters are not the source of the inherited differences we see in members of the same family or tribe

Nor, probably do inherited effects of past environments

account for the differences between the great racial divisions of man. Many people of course still think that the African is black because of inherited effects of hot sun, but it is much more likely that genes for skin colour, like others, change once in a while by mutation and that persons with genes for darker skin colour have been more successful in Africa than persons with fairer skin.

We should remember that the present opinion of most biologists on this question does not rest on absolute disproof of the inheritance of acquired characters. Such disproof would obviously be impossible, because many of the alleged instances of this kind happened so long ago that they cannot be studied now, and it is in any case impossible to prove a universal negative. I think biologists believe rather that positive proof has been provided of the origin by random mutation of most of the hereditary differences which have been studied in plants, animals and man. This view rests chiefly on the proof of the gene theory of heredity, for once heredity was shown to occur by means of genes which change by mutation, then the older views about the origin of variations became not so much wrong as unnecessary.

The discovery of the gene mechanism, which began with the work of Mendel, published in 1865, and the confirmation of the idea and its extension to all plants, animals and man are matters that underlie the development of the modern biological views about race which are described in the last chapter. Those who are interested in the details of the gene theory will find it described in the Appendix (page 41).

Another parallel stream of development in biology which had great influence on thinking about race was initiated by the great work of Darwin, published in 1859. He showed that the varieties of living organisms had reached their present condition by a process of descent with modification, guided by the principle of natural selection. In his theory, hereditary variations, of unknown origins, provided the raw material from which the environment selected the better fitted or adapted characters and combinations for survival. Once it was shown that variations arose by random mutation, the way to differentiation of races and species as particular collections of genes, fitted to particular environments, was open. Discussion of the details of this theory would take us too far afield, but some applications of it will be found in the next chapter.

IV. HOW RACES FORM

If all men living today are descended from common ancestors, and there is good evidence that this is the case, how has mankind become divided up into different races? History alone cannot answer this question, since the great groups of man had already become different before written history began. We must find out about it as we find out about other scientific questions, by studying the processes responsible for it.

We can ask ourselves: why should not all men have remained biologically alike? We studied that question in the last chapter and found that the elements of heredity, the genes, sometimes change by a process called mutation, and this gives rise to a great variety of genes. These, by coming into new combinations during reproduction (the baby has father's nose, mother's hair, and Uncle John's bad eye-sight) produce an almost endless array of kinds of people, so that literally no two persons are the same.

Now the process of heredity in man is such that we should expect this great variety to be retained indefinitely as individual variations, just as these continue to appear in any one family or population. Mutation is an important factor in the origin of individual variety, but it does not tell us how variation between groups arises.

To understand that, we have to remember that not only are people various, but also the environments which the world provides, and some of the genes and particularly some of the combinations of genes are more successful than others under certain conditions. We spoke of certain hereditary characters as being more successful in Africa, blondness for example being disadvantageous and darkness advantageous. Studies of animals and plants have shown that the proportion of the population having those combinations of characters which are advantageous in a certain place, as for example in a desert, tend to increase generation after generation. They gradually supplant the other combinations, although the latter may be useful in the mountains or in the forest where they tend to

increase with time, usually through there being more surviving offspring. This process, which Darwin called Natural Selection, tends to change the races and species of animals and plants so that each becomes fitted or adapted for life under a certain set of conditions. This apparently comes about by the more successful gene combinations multiplying more rapidly than the less successful ones. The same effect is even more obvious in domestic races of animals and plants, in which we deliberately select for breeding those types we want, and thus create races by artificial selection.

In addition to mutation and selection, a third factor is sometimes involved in shaping the particular collection of genes which becomes a biological race. It may happen that the frequency of a gene may increase or decrease in a locality, not because it confers some advantage or the reverse, but simply because of accidental or chance fluctuations, which are much more serious in a small population than in a large one. The extinction or spread of family names which occurs in small communities may be due simply to a run of luck in a family in the proportion of sons and daughters. In societies in which the name is transmitted through males only, a family with many sons would have its name spread in a small community, while one with no sons would have its name disappear, so that in neighbouring villages a name would be common in one and absent in the other. In large cities such fluctuation would not be noticeable, but small populations may diverge from each other by such accidents. Differences among races in the proportions of persons of the four blood groups seem to have come about in this way. Such accidents must have been of great importance in earlier stages of human history when the human reproductive communities must have been very small. This risk which new variants or combinations run in small populations has been called genetic drift.

Finally, after these factors have acted, it is obvious that migration and mixing of different groups may lead to changes in old races or the formation of new ones. This can be seen going on today. New races are forming in the Hawaiian Islands, for example, by the mingling of Chinese and European immigrants with the native people; and in the United States and in South Africa by intermarriage among the descendants of marriages between Negroes and Europeans.

If it were not for the operation of the four factors named above, a human population would remain in a steady state

in respect of its hereditary constitution. This was deduced from the laws of Mendel as long ago as 1908 and reached independently by an English mathematician, Hardy, and a German physician, Weinberg, whence it is usually known as the Hardy-Weinberg equilibrium principle. This principle states that, in large populations mating at random, the relative frequencies of the different varieties of each gene will remain constant.

Since biologically races are populations differing in the relative frequencies of some of their genes, the four factors noted above as those which upset the equilibrium and change the frequencies of genes are the chief biological processes responsible for race formation. They are: (*a*) mutations or changes in the elements of heredity, the genes; (*b*) selection, being differential rates of reproduction, fertility or survival of the possessors of different genes; (*c*) drift, or the accidents of gene sampling in small populations; (*d*) differential migration and mixing of populations.

None of these processes would result in hereditary differences among groups of people unless something interfered with the complete freedom of intermarriage among all persons which has been referred to as random mating, for otherwise all would be members of the same biological or reproductive group. Thus we must add a fifth factor of a different kind. This is isolation, geographical or social. Once the other factors are present, isolation is the great race-maker. If the whole population of the world constitued one marriage circle, in which any individual had an equal chance of marrying any other, then the great variety of people which is kept up by mutation and combination of genes would be distributed more or less evenly over the whole world. Obviously neither condition actually obtains.

The variety of the world's population is distributed in clusters. For example, most of the dark peoples are in one cluster in Africa, although another group occurs in Melanesia, most people with yellow skins are in north-east Asia, most blond people in northern Europe or countries settled by north Europeans, and so on.

Between these separated groups there is relatively little intermarriage. Choice of marriage partners is limited to those who live near, speak the same language, profess the same religion, and belong to the same class or caste.

These divisions of the world's populations did not always exist as at present. Once there were no human beings in the

American continents, nor in the islands of the South Seas, nor in Australia. There may even have been a time when the human race was actually one marriage community, because even today all races have many of their genes in common, as though they had all got them from a common source.

If it were not for the geographical and cultural barriers which separate people today, we could think of all of the genes in the human race as constituting one great pool. Whenever a new person was to be formed, two of each human gene would be taken from that pool and every kind of combination would be possible at each birth. Actually, of course, the genes are transmitted in sex cells, one from each parent, and it is two such cells, one male and one female, which form each new individual. But if any woman were equally likely to marry any man, then we could think of random combinations of sex cells and random combinations of the genes they contain.

But the world's population is obviously divided up into many different gene pools *within* which combinations occur more or less at random, but *between* which genes are less frequently exchanged because of rarity of marriage. These different gene pools or marriage circles are likely to differ in the genes they contain, that is, different mutations may occur in different separated populations; selection may change the proportions of genes in different populations; the changes may occur by accident or by different rates of migration or intermixture. But however the original difference between two populations may have arisen, the difference will persist only if something makes intermarriage between them infrequent, and this is why isolation is so potent an influence in forming different groups of people. Isolation is often partial; it is anything which tends to cut down exchange of genes between groups. We all know the ways in which our choice of marriage partners is limited. They are not only geographical, but religious, social, economic, linguistic, that is to say, the isolating factors are largely cultural. Thus a common biological community tends to be broken up by non-biological factors into sub-communities, which may then tend to become biologically different.

Races form because of the operation of biological processes. These are determined by the nature of heredity, which provides for a variety of stable hereditary elements, genes, transmitted according to regular laws or principles; and by

the nature of the environment, which is broken up into a variety of partially isolated habitats. Particular genes or groups of genes are more successful in (i.e., adapted to) certain environments, others in other environments. These views have been tested experimentally with a variety of plant and animal populations. They have only begun to be tested by observations on human populations, some of which are described in the next chapter, but the basic conceptions derived from experimental biology appear to be generally applicable to all bi-sexual animals including man.

V. A BIOLOGIST'S VIEW OF RACE

The groups that become partially separated and different owing to the operation of the factors described in Chapter IV go by many names: races, hordes, tribes. All of them have this in common, that they differ from other groups by maintaining a different proportion of the same kinds of hereditary elements—genes.

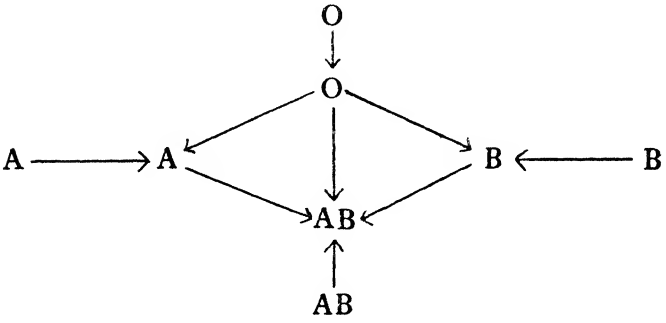
This is nowhere more clearly shown than in the distribution of the genes which determine certain properties of the blood. There are four kinds of people, called A, B, AB, and O These four kinds of persons differ in the substances they contain in their red blood cells.

It is well known that the red colour of human blood is due to red particles which float in the transparent straw-coloured fluid which forms the liquid part of the blood. As soon as blood is taken from the body and allowed to stand, it tends to congeal in a red mass which is called a clot. If the clot is allowed to stand for an hour or so, it contracts and a pale transparent yellowish fluid oozes out. This is called blood serum.

Blood has always played an important part in beliefs, not only about relationship but about the qualities of different persons. It turns out that some of these qualities of blood are quite specific. For example, it is possible to transfer blood from a strong healthy person to one who is ill or has lost a great deal of blood, but only if the transfer (transfusion) is made in specified ways. The rules governing blood transfusion were discovered 50 years ago, when it was shown that the presence or absence of certain substances in the red blood cells are responsible for the success or failure of blood transfusion. These substances in the red cells are called A and B substances, and A and B antigens.

In the serum are other substances which react with the substances in the blood cells. The substances in the serum are called antibodies. For example, if serum is taken from a person in the A group, it will cause clumping of the cells of a B group person when these are placed in it. Con-

sequently we say that the B persons have anti-A substances in their blood. Therefore if cells from an A person are transferred into the circulation of a B person, the cells of the A person will form clots which puff up some of the small blood vessels and this is likely to cause the death of the person who was to have benefited by blood transfusion. When all these combinations of cells and serum are carefully studied it is found that persons can give and receive blood according to the diagram below:



The blood type of each person is determined by his genes. One gene produces A substance, another B substance, and another no specific substance in the red blood cells. These genes are called A, B, and O. Every person can be easily placed in one of the four groups, O, A, B, or AB (Table I), and we find that the genes responsible for these groups are present throughout the world, although the proportions of these different genes differ somewhat from place to place and from race to race.

TABLE I.

Person of blood group	Has this substance in his red blood cells	Has these antibodies in his blood serum	Has these genes
O	A	anti-B	AA or AO
AB	B	anti-A	OO
B	A and B	none	AB
A	none	anti-A and Anti-B	BB or BO

TABLE II. *The proportions of persons belonging to each of the four blood groups in different populations (per cent).*

	O	A	B	AB
American Indians:				
North American Indian-Sioux	91	7	2	0
South American-Toba	98.5	1.5	0	0
Australian:				
Aborigines West	48.1	51.9	0	0
East	58.6	37.8	3.6	0
Europeans:				
English	47.9	42.4	8.3	1.4
Swedes	37.9	46.1	9.5	6.5
Greeks	42.0	39.6	14.2	3.7
Russians	31.9	34.4	24.9	8.8
Africans:				
Pygmies	30.6	30.3	29.1	10.0
Asiatic:				
Japanese	30.1	38.4	21.9	9.7
Chinese	34.2	30.8	27.7	7.3

These different groups of people have the same kinds of specific substances in the blood, and the variety in the substances is due to variation in the genes, which probably arose by mutation.

Related people who probably got their genes from the same source have similar proportions of the A and B genes. This produces the great cluster of blood group O in the American Indians, in whom B is rare or absent, while A is generally also uncommon. There is a group of Indians in Peru in which all persons tested were found to be of group O. Their nearest neighbours are a tribe with 90 per cent group O. Probably A and B were lost from the first tribe, either by accident when its ancestors migrated to a new home, or by some selective factor operating in the new environment.

Notice too the rise in the proportion of blood group B as we go east across Europe from England to Russia (Moscow).

There are some interesting situations in groups known to have split up by migration within historic time. The Ice-

landers are descended from Vikings from Scandinavia and "Westmen" from Ireland who settled on the island in the ninth century, A.D. Although the majority are supposed to have come from Scandinavia, and Iceland was politically united to Denmark until 1944, the blood types of the Icelanders are much closer to those of the Irish than of the Danes.

TABLE III. *Percentage of population in each blood group.*

	O	A	B	AB
Icelanders	55.7	32.1	9.6	2,6
Irish	55.2	31.1	12.1	1.7
Danes	40.7	45.3	10.5	3.5

That likeness is due to common descent and not to sharing a common environment is clearly evident in the case of the Basques, living near the Spanish-French frontier. They are unlike both their Spanish and French neighbours, who resemble each other more closely than either resembles the Basques.

TABLE IV.

	O	A	B	AB
Basques	57.2	41.7	1.1	0
French	39.8	42.3	11.8	6.1
Spanish	41 5	46.5	9.2	2.2

As a final example, two groups of people living near each other in Hungary are very unlike each other in blood group distribution. One group is composed of gypsies with a large proportion of blood group B like some peoples of western India, whence the gypsies migrated long ago. The other is composed of "natives", long settled in Hungary with less than half the proportion of group B. Similar evidence exists for other groups who live near each other. The reason, of course, is found in the rarity of intermarriage between the different groups. This shows that a common environment does not by itself cause convergence, and that there are

barriers other than geographical ones which cause peoples to remain distinct. Of course this would happen only if the genes retained their integrity and were passed on uninfluenced by the combinations in which they had taken part.

All these facts could be illustrated just as well by other human genes which can be classified objectively and accurately. The so-called M and N blood types, the varieties of the newly discovered Rh blood gene, genes for taste-blindness, colour-blindness, and others all appear in their several varieties in nearly all human populations but in *different characteristic proportions.*

Blood typing has certain obvious advantages over measuring or photographing in attempting to study the nature and origin of group differences. Blood typing immediately reveals the genetic constitution of the person tested, so that the distribution of these genes in a population is known from the blood group distribution. Blood typing prevents the loss of the individual in the group because in general there is no "average" blood type. There are only characteristic proportions in which the same elements are mixed.

These differences in proportions are racial differences, that is, they indicate partial separation of the population in which the different proportions are maintained. The differences may be just as great between populations living in the same city as between populations living half a world away from each other. In Table V are shown the blood group varieties in two caste communities in Bombay, as determined by two Indian investigators.

TABLE V.

	O	A	B	AB
Indians (Bombay C.K.P.)[1]	34.5	28.5	28.5	8.5
Indians (Bombay K.B.)[2]	51.0	24	20	5.0

[1] *Members of the caste community Chandraseniya Kayasth Prabhu.*

[2] *Members of the caste community Koknasth Brahman.*

The blood types of these groups are quite different, and differences like this were also found in six other gene-determined characters. They are in fact at least as different in

these traits as American whites and American Negroes, who are separated by the low frequency of intermarriage. These Indian communities are separated by customs which cause marriages to be contracted only between members of certain specified sections within the caste.

These conditions permit the maintenance of gene differences between the groups. No one hesitates to call such differences "racial" as between Whites and Negroes, everyone being aware that the ancestors of the Negroes came from Africa a few hundred years ago where they had been practically isolated from European populations. But there would be a good deal of hesitation in referring to the two Indian caste communities as belonging to different races; the members of these two caste communities have lived together in peace and mutual respect for 2,000 years or more. This is good evidence that biological racial differences are not themselves the cause of race friction or prejudice. Probably the members of these castes do not recognize the biological differences which the scientists found, and after getting on well together for so long we can be pretty sure that their behaviour will not be influenced by this new knowledge.

The important thing is not to have an easy and certain answer for every question about racial classification, but rather to understand, from such instances, the nature of racial differences. Once these are seen to consist of collections of individual hereditary elements which do not blend even within the same population, then we can see in a different light the external differences from which we had earlier formed ideas about the fixity of "racial types". When we look around us from this second point of view, we find a good many facts which fit together into a consistent picture.

In the first place no very radical changes in classification of the great branches of mankind are suggested when they are compared by the gene method.

Geographical isolation has undoubtedly been the great race-maker, and this is clearly reflected in the differences in the frequencies of several objectively scored genes as between European, African, Asiatic, American Indian and Australian racial stocks. Even those great branches are not discontinuously different, having most of their genes in common. European and Asiatic "intergrade" in eastern Russia and Siberia, Australian and Asiatic in the southern Pacific, and the other Pacific peoples show resemblances with, and no sharp differences from, Asiatics and Americans. Even the

Australians and Europeans, separated so widely (except for the recent migration of Europeans) show clear evidence of common origin.

The most recent racial classification of mankind based on the gene frequency method is that of Boyd (1950) who recognized five major races as follows: (*a*) European or Caucasoid, (*b*) African or Negroid, (*c*) Asiatic or Mongoloid, (*d*) American Indian, (*e*) Australoid. These can be characterized as groups by the relative frequencies of some eight genes, most of them concerned with blood antigens. It is obvious that they represent groups isolated geographically. The American Indians separated from their Asiatic ancestors only some 10,000 to 15,000 years ago, so they retain many mongoloid traits but still can be distinguished as a group. In addition to these, transitional groups are recognized, such as the peoples in the Pacific Islands, and in North Africa, and a hypothetical race not now in existence except as a small relic population, the Basques of Spain and France.

On the other hand, another study also published in 1950 by three American anthropologists, Coon, Garn and Birdsell, recognized 30 races, based largely on the classical criteria of physical type. Some of the 30, such as Neo-Hawaiian, American coloured and South African coloured are interesting as examples of races in the making. The authors thereby recognize that race is not something fixed and unchangeable, but a stage in the process by which human populations adapt themselves to special conditions. All of the 30 races above can be grouped into the same five categories recognized by Boyd and by anthropologists generally, since they are clearly based in geographical isolation.

It cannot be said at present that one classification is more correct than the other. The classification is in part a convenience and thus may be somewhat arbitrary, and determined by the purpose for which it is to be used. But it must be also a "natural" classification and express the evolutionary processes which have brought about the racial diversification of mankind.

The classification into a few large races is perhaps the one best justified. Races which have lived in one place for long ages seem to be fitted to live in just such a region. Biologists say they are " adapted" to the physical conditions, just as those plants which are best able to get along with infrequent rainfall or in extreme cold have survived in desert or mountain conditions.

Not much is known about the adaptive value of most physical characters in human races. Skin pigment appears to be advantageous where people are exposed to strong sunlight; great chest capacity and a large volume of the red blood cells which carry oxygen may be adaptations to high altitudes. Resistance to specific local infectious diseases must be an extremely important adaptive quality which may not be expressed in physical form.

In man, ability to succeed in a great variety of environments is connected with the most important way in which he differs from lower animals, that is, his ability to learn and to profit by experience. The adaptedness which local groups exhibit to their local environment is probably due to the particular sample of genes which came to them from their ancestors. Some of it is direct, that is by selection of genes such as those for resistance to a specific disease, which interact with tangible elements of the environment. Some of it is indirect, by selection of those genes which increase the mental adaptability or plasticity. The methods developed by medical science enabling men to live successfully in areas for which they had been physically unfit, such as Europeans in tropical jungle, are such indirect adaptations.

No race is uniform in respect to mental traits any more than with respect to physical traits. It is in fact this very variety within each group which permits its extraordinary adaptability. Somehow people seem to be found to accomplish successfully all the different tasks which are required in every human society. We can suspect but not prove that this is due to the multiplicity of genes influencing the brain and nervous system, just as there are so many concerned with other parts of the body; and that this variety is maintained by the same means as in other cases, that is, by the human habit of marrying the son or the daughter of someone whose genes are somewhat different from those in your own brothers and sisters. This keeps the gene pool stirred up and prevents the uniformity of mental constitution which would limit a group to only one kind of life or activity.

Fear is often expressed that this fate of sameness may overtake those who live in industrial societies in which a race of "machine slaves" is being bred. The same fear could have been expressed a few generations ago that those confined to the monotony of tilling the soil would become "slaves of the land". Yet the latter gave rise to the former. The variety of human genes, which permits a variety of responses

and hence fits us to live in a variety of environments both past and present, will not be changed by a few generations spent in one kind of environment.

Also groundless are the fears of "race suicide" and "race degeneration", about which we used to hear a great deal, especially in industrial societies. "Race suicide" is assumed to be brought on by abstention from reproduction on the part of the superior members of a society, so that the greater fertility of the inferior members would result in swamping out or replacing an upper by a lower class. Leaving aside the fact that "race" is used here in a different sense than previously defined, there is still no good evidence that the biological make-up of a population is altered very much by such differential birth rates. There is reason to think that people with higher incomes do not, as a class, have a different proportion of genes pertaining to such traits from those with lower incomes. We strongly suspect that genetic differences of this sort pertain to individuals and not to economic and social classes.

"Race degeneration" implies the fear that—as civilization increases, and with it our care for physically and mentally handicapped persons and our skill in treating them—their descendants will take over and the level of the whole race, any race, be thereby lowered. This assumes that the causes of the handicaps are generally hereditary and that the handicapped have higher fertility. The first is true to a limited extent; the second is unproved as a general statement, but known to be untrue for the severest mental and physical defects. The cures or proposals for "race improvement", or eugenics, involve in general prevention of reproduction of handicapped persons, which nature takes care of in some cases and which can be justified as a social measure in certain others, but which fails to reach the large numbers of defective genes which are hidden ("recessive") in normal persons. "Positive eugenics" would give social sanctions to increasing the birth rate of the "superior" as compared to the "inferior", but that is hardly practical until these distinctions are proved to be due to differences in genes and until there is agreement concerning in what way one class is "superior" to another.

VI. RACE SEPARATION AND RACE FUSION

Two processes are clearly in evidence in our human species. One of these is race formation, by which distinctive collections of genes are gathered together; the other is race fusion, by which these collections are dispersed. The essential condition for race divergence is always separation, partial or complete isolation, which reduces the frequency of marriage between two groups. We can call the group within which marriages are contracted the *marriage circle*. It has a kind of boundary around it, a wall which confines most of the people, but over which a boy or girl may occasionally climb in either direction to "marry outside". We can think of the population of the world as living within marriage circles of differing sizes. These circles overlap and permit some intermarriage between circles, but less than within a circle.

Now anything which affects the size of the circle, that is the number of people within the marriage circle, and the degree of separation between circles, will affect the distribution of genes. Every marriage circle is a potential race. I have already pointed out that members of two different caste communities in the city of Bombay are as unlike in the frequency of certain genes as are members of African and European marriage circles. Even of we did not know of the customs preventing marriage between members of these different castes, we should have to infer that they existed. Some of these caste communities are very large (several million) and others quite small (20,000 to 30,000).

On the other hand European royalty, whatever its origin, language, or nationality, belonged to one marriage circle It was a small circle, and cousin marriages were frequent. As a consequence, children were likely to get both members of a pair of genes from the same source, such as a common grandfather, and thus were likely to show the effects of recessive genes which would rarely come together in a larger marriage circle. If the genes had bad effects, this would decrease the physical qualities of the members and would appear as a "racial trait".

Although the whole population of ordinary people in Europe may have belonged at one time to the same marriage circle, it became broken up into smaller circles. Country people lived in vilages and usually married some one from the same or a nearby village. The same thing happened as in the royal families. Children would get two bad recessive genes from the same source, and then we had the particular type of idiot or dwarf or deformed person which could be recognized as the "village idiot". City people too were partly separated into different marriage circles, but more often the barriers to intermarriage were religious or social. The Jewish populations of Europe were largely separated from their neighbours and (when there was little travel) married within their own community, usually a small one. Certain hereditary diseases thus came to light more often and came to be known as "Jewish" diseases, although it was mating amongst relatives that brought them out, and nothing peculiar to their religious community. In this way the population of Europe tended to split up into small marriage circles and the groups tended to diverge. This divergence never proceeded very far, for the history of Europe, in numbers of human generations, is a short one, and peoples in other parts of the world, although they could recognize Europeans, could seldom distinguish the different varieties. Whether one recognizes few or many races in Europe is a matter of taste about which anthropologists do not agree.

The important fact for us in the present connexion is that the marriage circles tended to change as economic, social, and political conditions changed. The movement from country to city which the development of industry greatly accelerated, resulted in a very great enlargement of the marriage circles. Now boys met girls from different parts of the country and wherever other barriers were absent the expected took place. The incipient peculiarities of separated communities were merged in the larger group. The development of cheap transportation had an important effect, especially as between different countries. Most important for Europe, connexion with America became very close, and in the American cities members of different marriage circles met and became members of the same circle. Moreover, the social and economic class barriers tended to get lower as political democracy spread.

These considerations show only that the conditions tending to change gene distribution may be responsive to external

factors of many kinds. They do not explain why one group should spread and another contract. Sometimes this is due to pure luck, just as whether we are exposed to a fatal disease may be a matter of chance. Sometimes factors which are only secondarily biological will be decisive, such as customs of early or late marriage, decreed for religious or economic reasons, which determine the rate of natural increase of the group. Sometimes the conjunction of great military or religious leaders will cause one group to expand or migrate at a fortunate time while another disappears for no apparent biological reason.

These are cultural changes, and yet they have greatly affected the distribution of genes. The net effect in Europe and the Americas has been to increase the size of marriage circles, and thereby to reverse the tendency to isolation by which races tended to diverge. Genes in the European world now have a much greater mobility and will tend to spread themselves more evenly. One effect is to make it less likely that members of this large community will marry relatives and thus bring to expression those hidden recessives, many of them deleterious, which nearly everyone conceals. In this sense enlargement of the marriage circle is beneficial.

On the other side we often hear of the bad physical and psychological results of crosses between members of widely different marriage circles. As far as the physical side is concerned, this has never been established and is probably not true. All normal men, of whatever origin, are able to marry and produce normal children. There are none of those barriers amongst groups of men which separate the species of animals and plants. That the offspring of many kinds of mixed marriages have a hard time, being caught between two communities without belonging to either of them, is an unpleasant fact which has however no biological basis.

Also on the debit side might be the fact that—since race differences probably arose out of a process by which groups became fitted or adapted to their particular environment—with the lessening of the differences, the human race as a whole may become less well adapted. I don't think we need worry very much about this since, in one way or another, a man now tends to control his own environment. He is even learning to adapt it to his needs rather than the reverse, which is the only way open to other living things.

One valuable feature of race should not be forgotten. The limited amount of inbreeding which occurs within a marriage

circle tends to produce gene differences between different circles. When members of different circles marry, the children are likely to contain more gene pairs with unlike partners than the parents. In some animal and plant populations this condition appears to be conducive to greater biological vigour —the "mixed bloods" or hybrids are superior in some respects to either parent stock. In fact, it may be that variety itself is good because it makes unlike combinations commoner. We really know very little about this sort of thing in man, but the very mixed biological make up of all present-day human individuals and groups suggests there may be something in it.

Biologically, then, men belong to one mating circle, and share in a common pool of genes. There is thus no biological justification for race-hatred or prejudice. One should be careful to recognize this prejudice for what it is, and not try to conceal it behind a "scientific" rationalization.

The conditions of the modern world, deplorable as they are for many peoples over whom hangs the threat of insecurity and war, are nevertheless just those which tend to remove or reduce the factors which created biological race differences. If given a chance to continue in operation, they have the power to restore the unity which the human race lost by geographical dispersion.

Under these new conditions of closer relations amongst the peoples, there is no need to anticipate the decline of diversity. The variety will be intra-group rather than inter-group and will thus emphasize the uniqueness of individuals.

Quite apart from biological considerations, there are others that will probably be decisive in determining the future of race. Men are social beings and religious beings, and they must depend upon their immediate fellows regardless of how close they may be drawn to others in the world community. Attachment to place, to neighbours, to members of the same community of thought and spirit have been good things— in spite of all the abuses perpetrated in the name of race. We need not give them up, but we should extend to all other groups the tolerance and sympathy which we extend to our own people.

THE OPERATION OF HEREDITY

The clue to what used to be called the riddle of heredity was found nearly 100 years ago by Gregor Mendel, then a monk in the Augustinian Monastery at Brno (Czechoslovakia). Mendel was curious about how differences which distinguished races of plants were inherited. By studying the descendants of crosses between the different races of the garden pea, for example from a tall variety crossed with a dwarf one, he discovered certain rules by which we have been enabled to understand how heredity works, not only in plants but in animals and men as well. Mendel's laws, and others based upon them discovered since 1900, describe the operation of living units, genes, which form the basis of reproduction and heredity in all forms of life.

Now that we have been shown how to do it, I think we could deduce these rules from observing human parents and children. Suppose for example, that we examined the children of all the woolly-haired Norwegians referred to earlier. Since woolly hair is a new character in Norway, it is still rare and found only in relatives, and consequently woolly-haired people have always chosen straight-haired people as mates. When we count the children from such marriages, we find that each child can be easily classified as either woolly- or straight-haired and that the children of the two kinds are about equal in number. On the average, just half the children of a woolly-haired parent inherit woolly hair. If we suppose that each woolly-haired parent has inherited a gene for woolly hair from one parent and a gene for straight hair from the other, then we can guess that when the egg or sperm cells are formed, about half of them should get one kind of gene and the other half the other kind. The important thing that Mendel found was that for any single difference of this sort, parents always transmit one gene or the other, and never both and never a blend of mixture of the two. Since we know that each individual arises from the union of one sperm with one egg, we can predict that half the children should get one kind of this gene and half should get the other.

In the case above, the facts agree with the predictions: about half the children resemble the wooly-haired parent *in this trait.* Marriages among the straight-haired children of woolly-haired parents do not produce any woolly-haired children. Consequently woolly-haired people can conceal *but transmit* a gene for straight hair, so we say the straight-hair gene recedes from view or is *recessive,* while the woolly-hair gene is dominant. The same rule holds for many contrasted pairs of characters. If for example we test the children of parents who can taste a certain substance (phenyl-thio-carbamide), and add together the results in all those families in which some children can and some cannot taste this substance, we find that the "taste-blind" children constitute about one quarter of the whole. Each parent in this case can be supposed to transmit either a dominant gene for tasting *T* or a recessive gene for taste-blindness *t* to any child, and the possible combinations in the children should be *TT*, *Tt*, *tT*, and *tt*. Of these one quarter have two taste-blind (recessive) genes while three-quarters have at least one tasting gene. There are many instances of this, concerned with all sorts of characters—colour, mentality, blood type, and others—the appearance of which in the children certain predictions can be made. But by far the most important result of observations of this kind is to confirm the existence in man, of the alternative or particulate nature of heredity which Mendel discovered.

This means that the members of each pair of genes, of which one comes from the mother and one from the father, remain distinct, without influencing each other, so that a straight-hair gene is no different when it comes from a woolly-haired parent than when it comes from a straight-haired one. If it were otherwise, we should expect the distinction between straight and woolly hair to be lost and children from parents differing in hair form to be alike, showing a blend of the parents' characters. But the striking thing in families is precisely that the children are not alike, and the existence of genes in sharply different states accounts for the fact.

All this disposes of the old idea that children inherit by "blood". We know that when bloods or other fluids mix, the result is usually a uniform solution or blend, in which case persons with the same mixture of blood, such as brothers and sisters, should all be alike. The fact that they are unlike in particular ways causes us to give up the idea of "blood heredity" and think in terms of "gene heredity".

If heredity were transmitted by some kind of fluid we should also expect that in places where a great deal of "mixing of blood" goes on between peoples of different racial origins, we should find people coming more and more to resemble a common uniform type, as the mixture became more evenly diffused. Instead of this we find just the opposite. In the American cities, for example, where peoples of many races intermarry, you see not a uniform "mixed" population but an extraordinarily varied one, in which characters derived from two or more races are combined in a variety of ways.

The reason for this stubborn persistence of variety is the same reason which keeps distinct a lot of wooden and glass white balls which you might mix in equal numbers in a jar. Shake the jar as you will, you still have wooden and glass balls. If you now your in an equal number of black balls, half wooden and half glass, and shake the jar, you will not get gray balls or balls of any one kind. Actually when you draw out a ball, it may be any one of four different kinds; black wood, black glass, white wood or white glass. The variety has increased.

This is much like what happens when we begin to observe the children of woolly-haired parents. If we look only at their hair form there are just two kinds of children, woolly and straight-haired. If we look at their eyes, we may find in certain families some children with brown and others with blue eyes. That gives us four kinds: woolly hair with brown eyes, woolly hair with blue eyes, straight hair with brown eyes, straight hair with blue eyes. If we test each one for another trait, whether for example any particular child can or cannot taste PTC (phenyl-thio-carbamide), we find that some say it is bitter and others say it is tasteless. Now we have eight kinds of children as follows:

Hair	Eyes	Taste
woolly	brown	yes
woolly	brown	no
woolly	blue	yes
woolly	blue	no
straight	brown	yes
straight	brown	no
straight	blue	yes
straight	blue	no

Three alternative differences have multiplied themselves to make eight kinds of people. Mendel's idea of alternative heredity should thus lead, not toward uniformity or making everyone biologically alike, as the blending of blood would, but to an enormous and persistent variety. The genes which different people have will get into new—and practically always different— combinations in the children because (a) the genes do not change, or change so rarely by mutation that it can be left out of account, and they do not blend or contaminate each other; (b) people tend not to marry close relatives who might have similar genes from a common ancestor and thus tend to produce new combinations; (c) a human being has a very large number of different genes and this provides for a huge number of different combinations.

As we have just found, if two parents differ in only three pairs of genes, they can have eight kinds of children. We got this by multiplying two by itself three times. Differences in four pairs of genes would allow 16 different combinations; 10 gene differences would give 1,024 combinations. Perhaps you will not believe or appreciate the number we should get if we multiply two by itself even a few times more. For example, if there were 31 genes of each of which two forms such as A and a, B and b, etc., were represented in a population, the number of combinations of these would be greater than the present population of the world. There are certainly more than 31 genes which have become unlike, and we have thus a good reason for understanding what we see, namely that no two persons are alike in terms of gene combinations. We know that this enormous variety is in fact characteristic of all human groups. We believe that it rests first upon the inheritance of living units which can assume alternative forms by mutation, and second upon the reshuffling and recombination of these units during the process of reproduction.

Of course every person receives and transmits thousands of genes, since one half of his total store has come from his mother and half from his father. One member of each of his pairs of genes has come from his mother and the other member from his father. Thus in the usual case, denoting like genes such as old ones by capital letters, and recently changed or newer genes by small letters, what most of us will have received from our parents will be something like this:

From mother	Child	From father
A	AA	A
B	BB	B
C	CC	C
D	Dd	d
E	EE	E
F	FF	F
G	Gg	g
h	hH	H
.	.	.
.	.	.
.	.	.
Z	ZZ	Z

To resemble the actual facts, such a list would have to be extended through many alphabets.

These units need not be thought of as entirely imaginary, although it is true that they were invented as a way of explaining facts about heredity, just as the idea of atoms was invented to explain how matter behaves. It is possible to arrange the many genes which have been studied in animals, plants and man into maps which show how they are probably located with respect to each other. Many biologists working in different countries now agree on the forms of these gene maps, and predictions about offspring made on the basis of the maps can be verified—just as we can, by use of a geographical map or chart, predict the outcome of a journey. Such maps express something real, as an earth or sky map does.

Although no one has ever seen a gene and perhaps no one ever will see a gene (or an atom either), we have good reason to believe that genes are actual living particles. Biologists believe that the thousands of genes in a human cell, such as an egg or a sperm, are organized into strings of substance called *chromosomes*, of which each person has 24 pairs. One of these pairs has come from the mother, each of whose eggs contains 24, and one of each pair, or 24 altogether, came in the sperm from the father. These strings can be seen and studied with powerful miscroscopes, and they behave exactly as though they were composed of genes. In fact there is good reason to believe that each group of genes, which in some animals and plants has been mapped, corresponds to one of the chromosome strings which can be seen.

It has been found possible also to cause chromosomes to

change by treating them with radiation or certain chemicals, and these are the same agents that cause genes to change. In fact once in a while it is possible to show that when a piece of chromosome has been lost, owing to injury by X-rays, the genes assigned to that place on the "map" have also been lost from the heredity passed on to off-spring. Now radiation would not strike *imaginary* elements, nor would one have imagined, by chance, the same system as pertaining to unseen genes as to visible chromosomes.

Although human genes have not been very well mapped as yet—since only one generation of men has passed since these rules were first widely recognized—there is good reason to suppose that human chromosomes consist of strings of genes like those shown below.

In the sketch, one of the longer paired chromosomes had come from the mother and one from the father, and the same is true of the shorter. Each letter stands for a pair of genes. The members of each pair of genes are known to occupy similar positions, actually opposite each other, in the members of the same pair of chromosomes. This is the kind of system which governs the arrangement and transmission of genes. About eight years after Mendel's rules were rediscovered in 1900, an important consequence of the genic nature of heredity, known as the equilibrium principle, was worked out by Hardy and by Weinberg. Suppose a person had received gene A from one parent and gene a from the other, so that we described him as Aa. The possible combinations of these genes in the offspring would be:

Egg		Sperm		Child
A	×	A	=	AA
A	×	a	=	Aa
a	×	A	=	aA
a	×	a	=	aa

The possible outcomes occur in the proportions:

Egg	Sperm	Child
1/4 AA	1/2 Aa	1/4 aa
or 25% AA	50% Aa	25% aa
or 0.25 AA	0.5 Aa	0.25 aa

These are merely different ways of expressing the same proportion.

Now suppose there is a large number of people, all children of marriages of Aa with Aa, and that these people are all of them going to choose their marriage partners for reasons which have nothing to do with the A gene. We could imagine them all shut up in a huge compound blindfolded, and agreeing to marry the first person of the opposite sex with whom they made contact. The possible combinations of marriage partners would be as follows, with the distribution of A and a among the children given in the cells of the chequerboard below.

		Women		
		1/4 AA	1/2 Aa	1/4 aa
Men	1/4 AA	1/16 AA	1/16 AA 1/16 Aa	1/16 Aa
	1/2 Aa	1/16 AA 1/16 Aa	1/16 AA 2/16 aa 1/16 aa	1/16 Aa 1/16 aa
	1/4 aa	1/16 Aa	1/16 Aa 1/16 aa	1/16 aa

When the different combinations in the children are counted up they turn out to be;

4/16 AA	8/16 Aa	4/16 aa	or
1/4 Aa	2/4 Aa	1/4 aa	

The proportions in the children are the same as in the parents. Indefinite repetition for any number of generations under these conditions would not change the proportions on the conditions that mutation from A to a either does not occur, or occurs at the same rate from a to A; that there is no discrimination in choice of marriage partners with respect to A or a (random mating); and that people of the three types Aa, Aa, and aa are equal in fertility, longevity, and the like. With a little more calculation, it could be shown in the same way that, under constant conditions as above, any gene of which the two different forms such as A and a are present in different proportions in the population, such as 90 per cent A and 10 percent a, will retain these proportions *indefinitely* in a large population where marriages are contracted at random

with respect to that gene. Matings moreover are necessarily at random as regards a gene the effect of which cannot usually be known to the marriage partner, such as the blood group, or the taste reaction to a certain chemical, such as PTC. In these cases we know that the genic variety of a human population is retained.

The equilibrium principle, a most important corollary of Mendel's first law, means that any crossbreeding population such as a human one will tend to remain in the same state, unless: (*a*) genes change by mutation; (*b*) genes are discriminated against by natural or artificial conditions; (*c*) genes get accidentally increased or decreased in proportion in very small populations; (*d*) genes get added to or substracted from the population by migration.

These, when aided by isolation between the population in which such changes have occurred, produce the differences in gene proportions which are the criteria of race differences.

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